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TIMBER—CONCRETE COMPOSITE DECKS

FOR
BRIDGES—PIERS—DOCKS—RAMPS—
BUILDINGS—AND OTHER STRUCTURES
REQUIRING HEAVY DUTY FLOORS

SERVICE BUREAU
AMERICAN WOOD-PRESERVERS' ASSOCIATION
CHICAGO, ILLINOIS

FRANKLIN INSTITUTE
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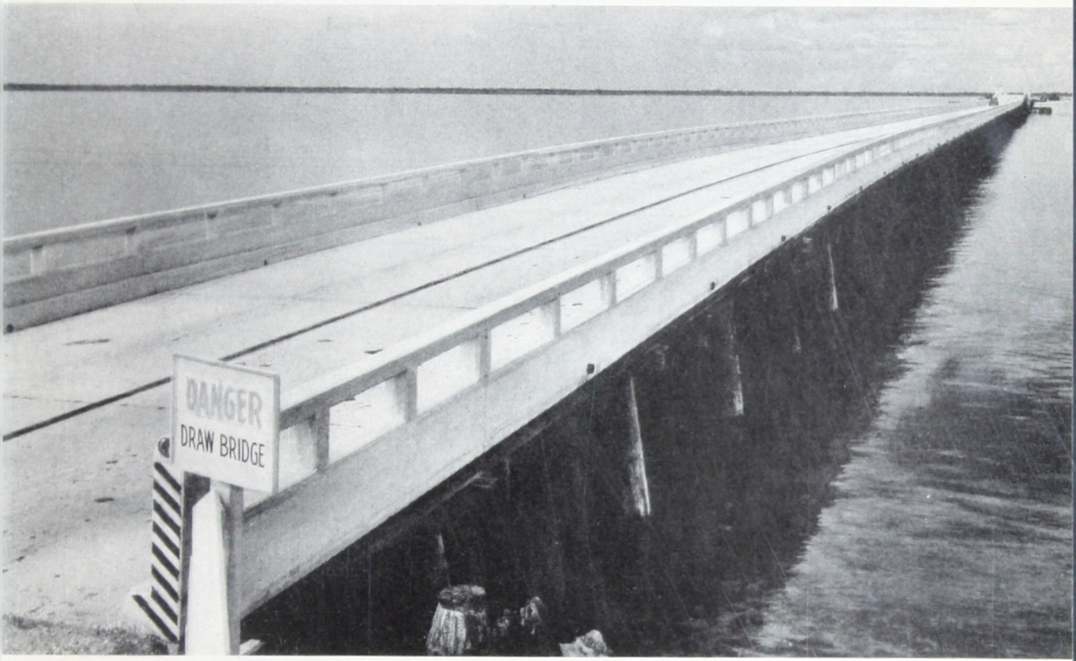


Creosoted Timber-Concrete Composite Deck on Creosoted Piles over a Portion of Tampa Bay, Florida, Built in 1933 and Financed by the Reconstruction Finance Corporation. This 3200-Ft. Structure Has Required No Maintenance During Eight Years' Service under Heavy Traffic

APRIL 1941

FOREWORD

Experience teaches the important lesson that simplicity of design is invariably the most significant factor in good engineering construction. Thus, whatever progress may be made in structural design—the achievement of greater economy, the improved use of materials, the enhancement of appearance, or better adaptability to specific conditions—true success, in the final analysis, will be measured in terms of simplicity.

The composite timber-concrete deck or slab construction described and analyzed in these pages is presented as a forward step in design. Aside from its more obvious advantages, the construction will have fundamental appeal to the engineer by reason of its faithful adherence to the principle stated above.

Many desirable characteristics, structural and otherwise, heretofore frequently lacking in timber structures, but inherent in the composite timber-concrete design, materially extend the field of service in which timber structures will find useful application. Nor need the engineer be restrained in aesthetic expression, since details of design lend themselves readily to architectural treatment.

This presentation of design principles, although brief, is sufficient for analysis of the composite assembly in whatever form it may be used. As a matter of convenience, tables and diagrams provide the busy engineer with a rapid means of selecting adequate sections for bridge, pier and other heavy duty decks, without tedious calculations.

This work has been undertaken and the use of composite construction advocated over a wide field in full recognition of the responsibility of the engineer to his clients and with full confidence that the design will prove advantageous to owner, engineer, and the general public. With this purpose in mind the subject is here presented.

TIMBER—CONCRETE COMPOSITE DECKS

TIMBER-CONCRETE COMPOSITE SLAB ASSEMBLY

THE treated timber-concrete composite deck may be described briefly as a slab in which a laminated base made up of treated timber plank is so rigidly interlocked with a portland cement concrete mat that the assembly is transformed into a unit adequate for bridge decks designed for the heaviest standard highway loadings or for piers, docks, warehouses, ramps or other structures requiring heavy-duty floors.

Joist and stringer systems are not required; and the concrete mat, in addition to forming an integral part of the supporting medium, provides an excellent and durable surface for vehicular traffic of all kinds.

This type of slab has been built and used successfully since 1932 for highway bridges and other structures in the United States and Canada by the governments of both countries and many other public and private agencies.

The timber base of the composite slab is made up of 2-in. plank ranging in depth from 4 to 12 in. and laid on edge with alternate plank raised from 1$\frac{3}{8}$ to 2 in. to form longitudinal grooves. The same effect may be obtained by using plank of two widths and alternating them in the assembly. Into the grooves thus formed are driven small trapezoidal structural-grade steel plates called shear developers (see Fig. 1), which extend a short distance, usually about ½ in., above the top of the high laminations and are embedded in the concrete mat, thus providing shear connection at the junction plane and combining the assembly into a unit with an effective beam depth equal to the overall thickness of the two materials.

TIMBER BASE

For span lengths ordinarily used in trestle construction all plank should be full panel length, usually laid immediately on the support in a direction parallel to the roadway center line. In multiple span construction, where a continuous, unbroken deck is often desirable, one-third of the laminations are butt jointed over the support centers and one-third at or near each quarter-span point, the joints being made in regular rotation. In this arrangement two-thirds of the strips extend across and are effective at any of these points, and a full timber section extends throughout the midspan reach between quarter points. Other arrangements of the timbers are possible, but at least two-thirds of the strips should be continuous across splice points.

SHEAR DEVELOPERS

Standard dimensions of the shear developers and their position in the assembly are shown in Fig. 1. They have a thickness of 3/32 in., and when driven their bases protrude ½ in. above the timber to engage the concrete mat. They are driven in slots cut by a suitable tool and spaced accurately in conformance with the plans. However, slight shifts in spacing should be made to avoid any knots in the timber which would prevent effective seating of the shear developer. As a rule, three men will cut the recesses and set 2,000 shear developers per working day.

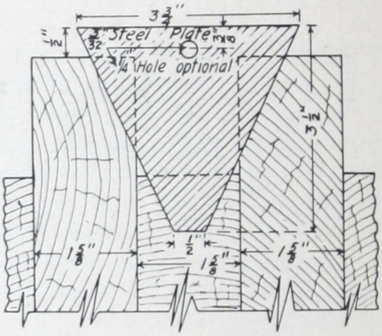
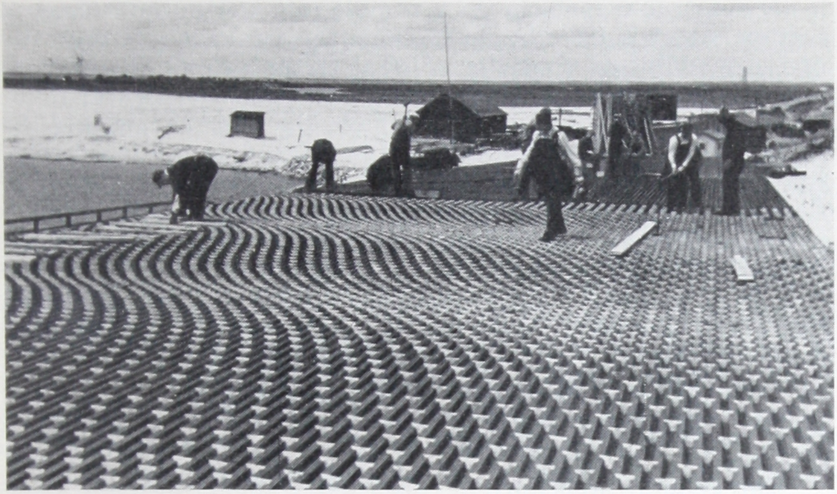


Fig. 1—Standard Shear Developer in Timber Base

UPLIFT SPIKES

In addition to the shear developers, uplift spikes are driven into the raised laminations of the timber sub-base at intervals of from 2 to 4 ft. These have a good penetration in the timber, and their protruding heads are embedded well in the concrete to preclude any tendency to vertical separation between the concrete and the timber due to the curling action of concrete induced by differential temperatures on its top and bottom surfaces. This arrangement places the spikes in position for the most effective restraint. While no value is allotted to the spikes in computing the shear connection, they do effectively reinforce it.



Placing Shear Developers in the 700-Ft. Indian River Inlet Bridge Built by the State Highway Department of Delaware in 1940. Spacing of Shear Developers in Base of Composite Deck Gives Appearance of Ogee Curves

CONCRETE MAT

The concrete mat is reinforced for shrinkage and temperature stresses to prevent cracking. A usual pattern for the slab reinforcement consists of a mesh made up of 3/8-in. or 1/2-in. round bars placed on from 9 to 12-in. centers, both longitudinally and transversely. In continuous spans, where negative bending occurs over the supports, sufficient tensile steel is added to take care of the calculated stresses. Bars about 1/2-span length are placed between the longitudinal slab bars and staggered in longitudinal direction to avoid an abrupt change in pattern. Alternate bars should extend across the joints in the timber base near the quarter points. The longitudinal bars preferably should be spliced at midspan and not over a support.

PREMISES OF COMPOSITE SLAB DESIGN

The combination in a structural member of two elements having different mechanical properties requires the formulation of definite premises for design. The dead load and live load stresses must be segregated and applied to the proper elements. In continuous beam or slab construction the distribution of bending moment between midspan and support will depend upon the elastic properties of the assembly. To determine the position of the neutral axis, moment of inertia, and section modulus, it is necessary to transform the assembly into a hypothetical wood section, which is done by multiplying the steel area by the ratio of the modulus of elasticity of steel to that of wood, which is usually taken as 18.75 for southern pine and Douglas fir.

The critical condition for which the member should be designed exists when the slab is first placed in service, before the concrete has attained its ultimate modulus of elasticity. Consequently, it is conservative to treat the assembly as a homogenous timber beam throughout the reaches where the concrete will be in compression, i.e., $E_c = E_w$. Where the timber section will be in compression, as in continuous spans over supports, the concrete is considered to have no value in tension. The negative bending moment, therefore, is resisted by the steel in tension and by the timber in compression.

DEAD LOADS

The general procedure in constructing timber-concrete composite slabs is first to assemble the treated timber subdeck; then to place the shear developers, uplift spikes, and reinforcement bars in the order named; and finally to pour the concrete surface. The entire dead load of timber and concrete falls to the timber section alone, and not to the composite assembly.* Thus, the first step in the design of the composite deck is the calculation of the dead load stresses in the subdeck.

In continuous span construction the calculation of stresses depends upon the relative magnitude of the positive and negative bending moments at critical points. Because of the joints in the timber sub-base, there is no known theoretical basis on which to calculate these moments in accordance with the action of a continuous beam of variable moment of inertia. Consequently, recourse has necessarily been had to test loadings to determine these factors. Such tests have shown that for a continuous timber subdeck with joints as above described the positive and negative bending moments for uniform dead load in interior spans are very nearly equal. Each, for all practical purposes, can be taken as 50 per cent of the simple span dead load moment; and, of course, they occur simultaneously. Positive moments in end spans will be slightly greater, usually assumed at 60 per cent of the simple span moment.

LIVE LOADS

The live load stresses are resisted by the composite section. To determine the forces acting on a given width of slab it is necessary to fix the lateral distribution of a concentrated load.

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*Centering for support of composite decks may be required in exceptional cases.

Lateral Distribution

Tests by the Maryland State Roads Commission show a distribution of 15.1 ft. for a single live load placed at the center of an ordinary trestle.* When the effect of passing wheels placed in accordance with standard clearance diagrams is taken into consideration, the lateral distribution for a critical concentrated load is 5.1 ft.** It has been customary, however, to assume a somewhat narrower load distribution for shear than for moment calculations, since the critical position of the load for maximum shear will be closer to the support. Thus the distribution for shear calculations is taken at 4.0 ft.

DESIGN ASSUMPTIONS

(1) $\frac{E_c}{E_w} = 1$

(2) $\frac{E_s}{E_w} = 18.75$ (for Douglas fir and southern pine)

Where
E_c is modulus of elasticity for concrete
E_w is modulus of elasticity for wood
E_s is modulus of elasticity for steel

(3) Lateral distribution for concentrated load:
For moment, $W = 5.0$ ft.
For shear, $W = 4.0$ ft.

Where W is equivalent width of slab over which a concentrated load is uniformly distributed

(4) Distribution of bending moments in continuous spans:

Dead Load: Both positive and negative movements are taken as 50 per cent of the simple span dead load moment in interior spans; and as 60 per cent in end spans.

Live Load: Positive moment is taken as 70 per cent and negative moment as 50 per cent of the simple span live load moment in interior spans; and 85 per cent and 40 per cent, respectively, of the simple span moment in end spans and 2-span structures. Maximum positive and negative moments do not occur simultaneously.

(5) Working stresses:
(a) Timber: According to grades specified, viz., 1200f, 1400f, or 1600f.
(b) Concrete: 800 lbs. per square inch in compression.***
(c) Steel: 18.000 lbs. per square inch.
(d) Shear Developers: 1750 lbs. each for $\frac{3}{32}$-in. thick steel plate in groove 2 in. or less in width.

DESIGN

Figs. 2 (a), (b), (c), and (d) show typical design details for a highway bridge with span lengths of 20 ft. for the standard

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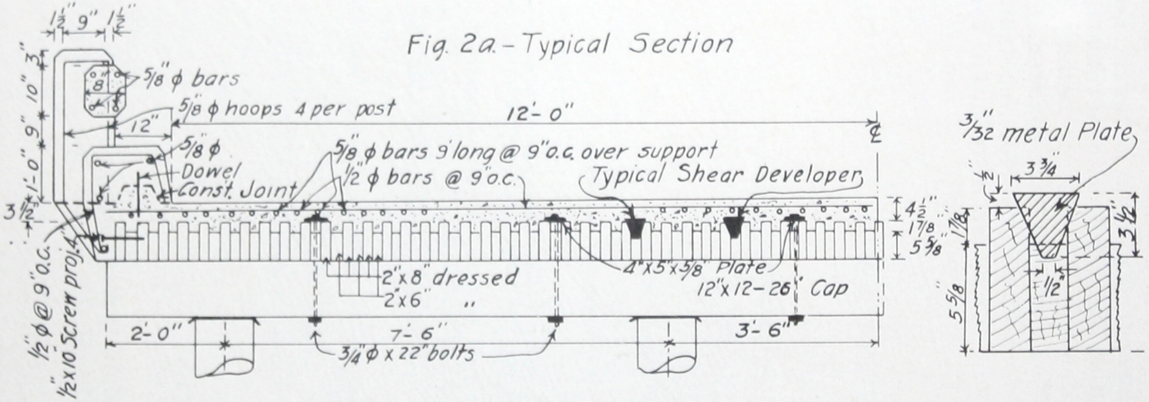
*See Wood Preserving News, March 1939, p. 27, or Proc., American Wood-Preservers' Ass'n, 1939, p. 272.

**By critical concentrated load is meant one of the interior heavy wheels of two passing load units in accordance with standard clearance diagrams.

***Working stress for concrete in compression is taken at 800 lbs. per square inch. Some designers use 900 lbs., which, of course, gives a somewhat higher resisting moment for the midspan composite section.

Fig. 2a.-Typical Section



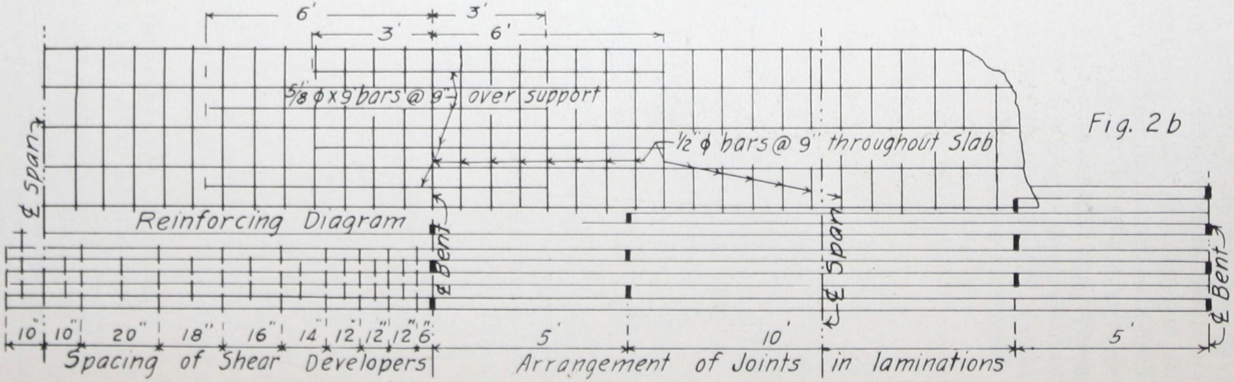

6'
3'
3'
6'
5/8" φ x 9 bars @ 9" over support
½" φ bars @ 9" throughout Slab
℄ Span
Reinforcing Diagram
℄ Bent
℄ Span
℄ Bent
10" 10" 20" 18" 16" 14" 12" 12" 12" 6"
5'
10'
5'
Spacing of Shear Developers
Arrangement of Joints in laminations

Fig. 2b

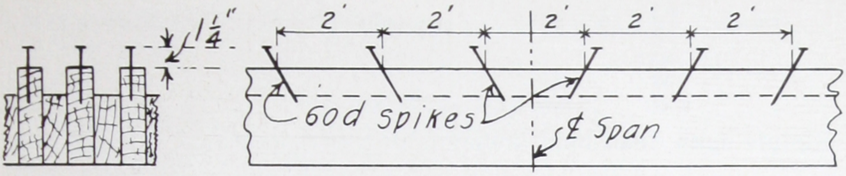


Fig. 2(c).—Spacing and Location of Uplift Spikes

H-15 loading. Detailed calculations are made below for an interior span of the bridge shown in this figure. The timber subbase consists of alternating 2 x 6-in. and 2 x 8-in. plank laid on edge, spiked together, and covered with a concrete surface, increasing from 3½ in. at the curb to 4½ in. at the roadway center to provide a 1-in. crown on the roadway surface. All plank are dressed to a standard thickness of 1⅝ in. and spiked as indicated. The top and bottom surfaces of the wood laminations lie in true horizontal planes, thus maintaining a uniform depth of groove. Ordinarily the standard dressed depth of 2 x 6-in. plank is 5⅝ in. In the example below it will be taken as 5½ in. Standard dressed depth of 2 x 8-in. plank is 7½ in. as shown in cross section. A 1-ft. width of slab is assumed in the calculations.

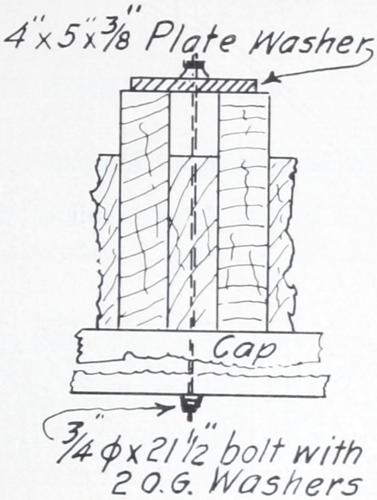


Fig. 2(d).—Details of Deck Anchor Bolt

DEAD LOAD MOMENT

Timber: Average thickness—6½ in.
Weight—60 lbs. per cubic foot

Concrete: Average thickness—5½ in.
Weight—150 lbs. per cubic foot

The total dead load is, therefore,

Timber: $\frac{6.5}{12} \times 60 = 32.5$ lbs. per square foot

Concrete: $\frac{5.5}{12} \times 150 = \underline{68.5}$ lbs. per square foot

Total 101.0 lbs. per square foot

Simple span dead load moment for 20-ft. span:

$$\frac{101 \times 20 \times 20 \times 12}{8} = 60{,}600 \text{ in. lbs.}$$

For interior spans this moment is distributed:

Positive moment $= 60{,}600 \times 0.5 = 30{,}300$ in. lbs.

Negative moment $= 60{,}600 \times 0.5 = 30{,}300$ in. lbs.

BEAM ELEMENTS FOR 12-IN. WIDTH OF SLAB

Wood Section at Midspan

In Fig. 3 each height of laminations has a width of 6 in.

y = distance from base to center of gravity of the section

$$\begin{array}{rl} 6 \times 7\frac{1}{2} = & 45 \\ 6 \times 5\frac{1}{2} = & \underline{33} \\ & 78 \end{array} \qquad \begin{array}{rl} 45 \times 3.75 = & 168.75 \\ 33 \times 2.75 = & \underline{90.75} \\ & \overline{)259.50} \\ y = & 3.33 \text{ in.} \end{array}$$

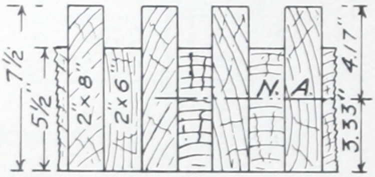


Fig. 3.—Wood Section at Midspan

Moment of inertia, wood only:

$$\frac{6 \times (4.17)^3}{3} = 145.0$$

$$\frac{6 \times (2.17)^3}{3} = 20.4$$

$$\frac{12 \times (3.33)^3}{3} = \underline{147.6}$$

$$I_1 = 313.0 \text{ in.}^4$$

Wood Section at Support

In Fig. 4 only two-thirds of the plank strips are continuous over the support and the section may be sketched as shown to simplify calculation. The moment of inertia is therefore ⅔ of the midspan section, or ⅔ x 313.

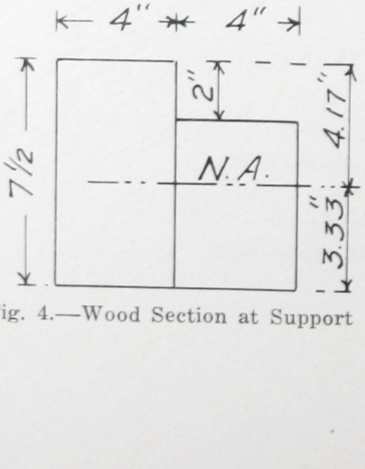


Fig. 4.—Wood Section at Support

Hence $I_2 = 208.70$ in.^{4}

and $y = 3.33$ in.

Composite Section at Midspan

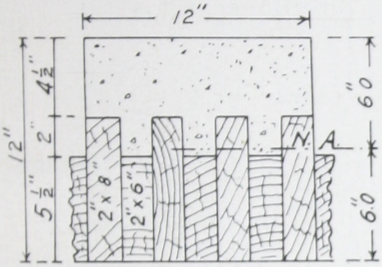


Fig. 5.—Composite Section at Midspan

The section is considered homogeneous.

Therefore,
$$y = 6.00$$
$$I_3 = \frac{12 \times (12)^3}{12} = 1728 \text{ in.}^4$$

Composite Section at Support

Because of joints in the plank strips at supports, only two-thirds of the laminations are effective. Each height of lamination in a 12-in. width of slab has therefore a width of 4 in., instead of 6 in. as at midspan.

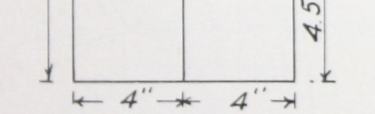


Fig. 6.—Composite Section at Support

$$\begin{array}{rrl} y = 30. & \times\, 6.00 = & 180.00 \\ 22. & \times\, 7.00 = & 154.00 \\ 12\,56 \times & 0 = & 0.00 \\ \hline 64.56 & &)\,334.00 \\ & y_s = & 5.18 \text{ in.} \\ & y_w = & 4.57 \text{ in.} \end{array}$$

Steel: $\left.\begin{array}{l} \frac{5}{8} \text{ in. } \phi \text{ @ } 9 \text{ in.} \\ \frac{1}{2} \text{ in. } \phi \text{ @ } 9 \text{ in.} \end{array}\right\} =$ 0.67 sq. in. per foot width of slab

and $0.67 \times 18.75 = 12.56$ sq. in. of wood

$$\frac{4 \times (2.93)^3}{3} = 33.6$$

$$\frac{4 \times (0.93)^3}{3} = 1.0$$

$$\frac{8 \times (4.57)^3}{3} = 254.4$$

$$12.56 \text{ x } (5.18)^2 = \underline{336.6}$$

$$I_4 = 625.6 \text{ in.}^4$$

DEAD LOAD STRESSES

Tension at midspan: $f_w = \frac{30{,}300 \times 3.33}{313} = 322$ lbs. per square inch*

Compression at support: $f_w = \frac{30{,}300 \times 3.33}{208.7} = 483$ lbs. per square inch

LIVE LOAD STRESSES

For the H-15 loading, one wheel imposes a load of 12,000 lbs. The load on a 1-ft. width of slab is, therefore,

$$\frac{12{,}000}{5.00} = 2400 \text{ lbs. per foot width of slab}$$

Simple span moment : $\frac{1}{4} \times 2400 \times 20 \times 12 = 144{,}000$ in. lbs.
Positive moment (interior spans) : $144{,}000 \times 0.70 = 100{,}800$ in. lbs.
Negative moment (interior supports) : $144{,}000 \times 0.50 = 72{,}000$ in. lbs.

Midspan

Tension in wood: $f_w = \frac{100{,}800 \times 6.00}{1728} = 350$ lbs. per square inch

Compression in concrete: $f_c = \frac{100{,}800 \times 6.00}{1728} \times 1.3 = 455$ lbs. per square inch

Where 1.3 is the 30 per cent impact allowance

Support

Compression in wood: $f_w = \frac{72{,}000 \times 4.57}{625.6} = 527$ lbs. per square inch

Tension in steel: $f_s = \frac{72{,}000 \times 5.18}{625.6} \times 18.75 \times 1.3 = 14{,}525$ lbs. per square inch

Where $18.75 = \frac{E_s}{E_w}$

MAXIMUM COMBINED STRESSES

Timber

Midspan: $322 + 350 = 672$ lbs. per square inch
Support: $483 + 527 = 1010$ lbs. per square inch

Concrete

Midspan: Total stress = 455 lbs. per square inch

Steel

Support: Total stress = 14,525 lbs. per square inch

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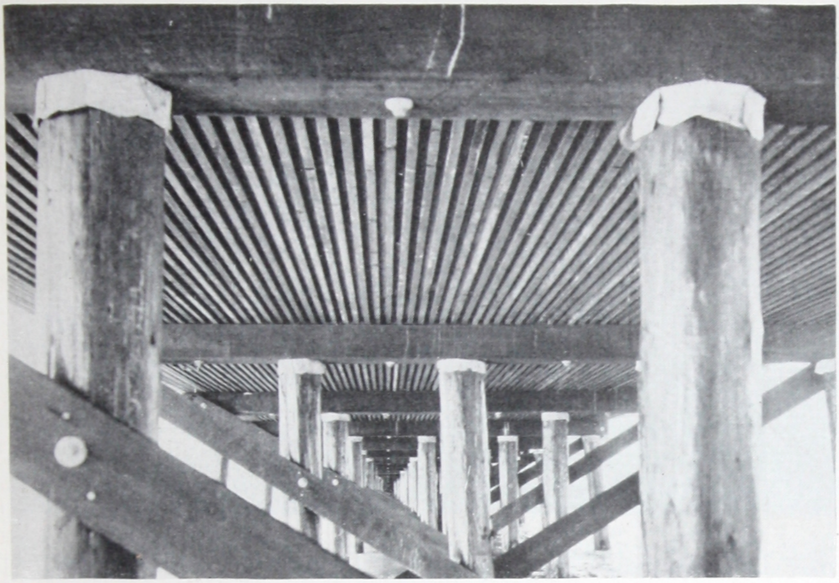
*Distance y to bottom fiber is used in computing wood stress. A somewhat higher dead load stress is developed at the top of the wood section, but top fibers are virtually on the neutral axis of the composite section where the live load bending stress is negligible. The maximum bending stress—combined live and dead load stress—is, therefore, developed at the underside of the slab.



Courtesy, Bureau of Public Roads

Under Side of Composite Deck, Showing Staggered 2 x 8-In. Creosoted Plank and Pile Substructure. This Bridge Connects the Mainland with the Site of Fort Pulaski National Monument on Cockspur Island, near Savannah, Georgia. View of Finished Bridge Appears on Page 14

Spacing of Shear Developers (See Fig. 2b)

The shear connection is designed for live load only. Lateral load distribution will be 4 ft. as stated in premise. Critical position of load unit for calculating shear will be at three times the depth of slab from support, or, in this case, 3 ft. Since this point is near splices in the timber base, the net section only is considered.

Effective load per foot width $= \frac{12,000}{4} = 3000$ lbs.

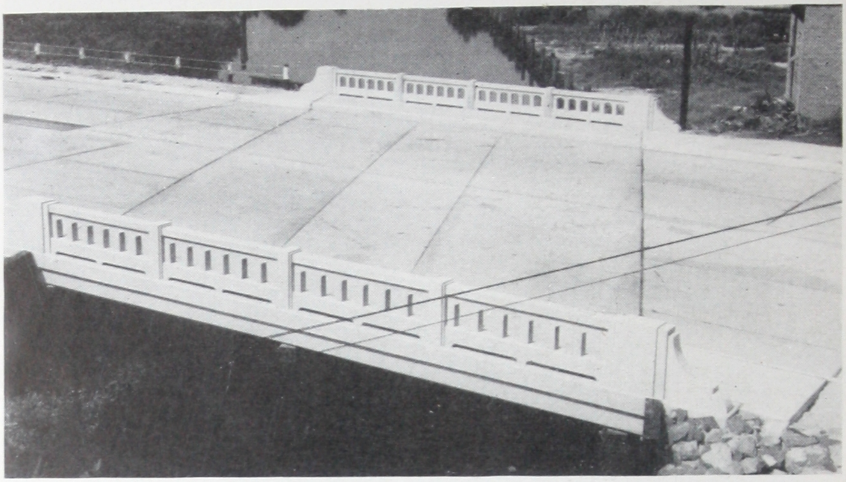
Adding 30% impact $= 3000 \times 1.3 = 3900$ lbs.

End reaction $= 3900 \times \frac{17}{20} = 3315$ lbs.

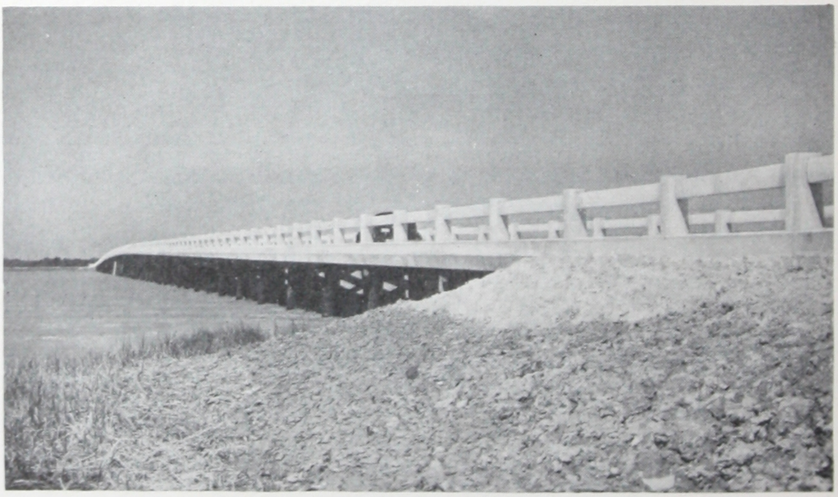
Net section: $(12 \times 12) - (2 \times 7.5) - (2 \times 5.5) = 118$ sq. in.
(Note.—Splices eliminate two laminations from the section.)

Average unit shear $= \frac{3315}{118} = 28.1$ lbs. per square inch

Maximum shear at neutral axis: $28.1 \times 1.5 = 42.2$ lbs. per square inch
Total horizontal shear on 1 sq. ft. is, therefore, $42.2 \times 144 = 6077$ lbs.

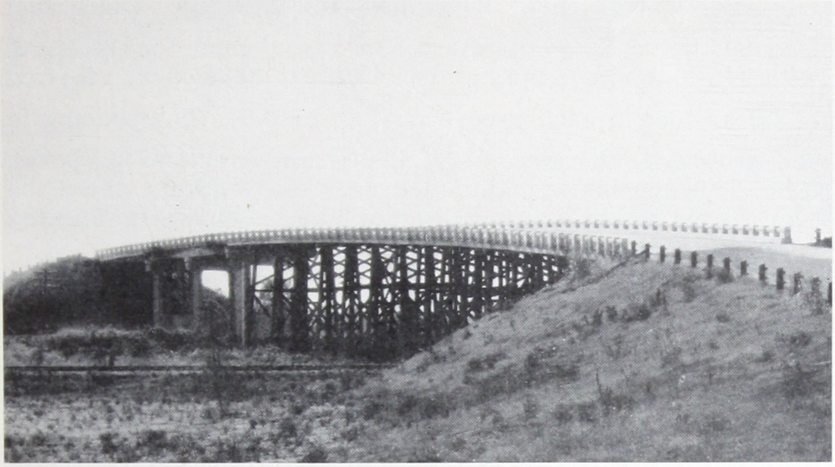


Two-Span Bridge with Composite Deck at Salisbury, Maryland. This is a 43-Ft. Bridge Built on a Skew, with a 56-Ft. Roadway and Two 8-Ft. Sidewalks. Loading Tests Referred to on Page 7 Were Made on This Bridge

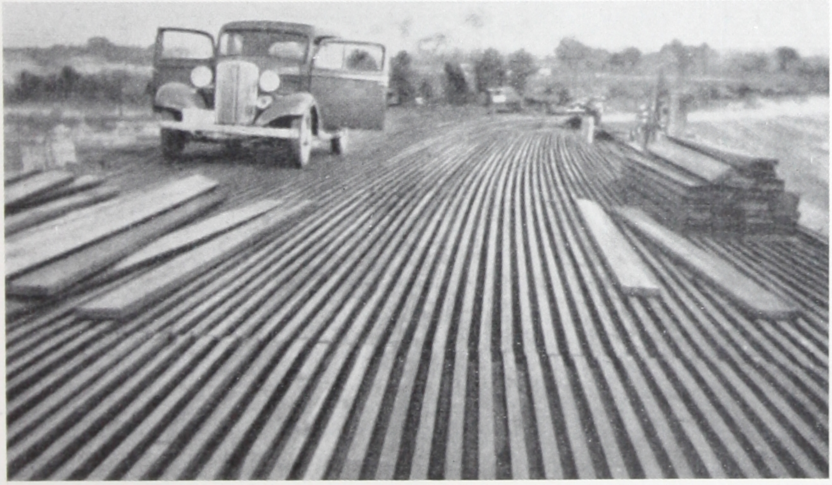


Courtesy, Bureau of Public Roads

This 1300-Ft. Composite Deck Bridge near Savannah, Georgia, Was Built by the U. S. Bureau of Public Roads for the National Park Service and Opened to Traffic in 1938



Composite Deck on 500-Ft. Grade Separation Structure Built near Montgomery, Alabama, in 1937 by the State Highway Department. Superelevation for the 5-Degree Curve Is Framed in the Pile Bents



Creosoted Timber Base of Bridge Shown Above. Flexibility of the Individual Laminations Simplifies Bridge Construction on Curves. The Subdeck Was Utilized for Construction Traffic

The working value of the shear developers is 1750 lbs. each, and $\frac{6077}{1750} = 3.47$ shear developers required per square foot of contact area. Since there are 3.69 grooves per foot of width (with $1\frac{5}{8}$-in. strips), the number of shear developers required per linear foot in each groove is $\frac{3.47}{3.69}$, or 0.94. The spacing in each groove is, therefore, 12.7 in., or for practical purposes, 12 in. This spacing is maintained near the support, where the shear is a maximum, and increased to 20 in. at midspan. Spacing of the shear developers is shown in Fig. 2b.

MISCELLANEOUS DETAILS

Substructure

Figs. 7(a), (b), and (c) show details of typical pile bent, nailing details commonly used, and details of expansion joint

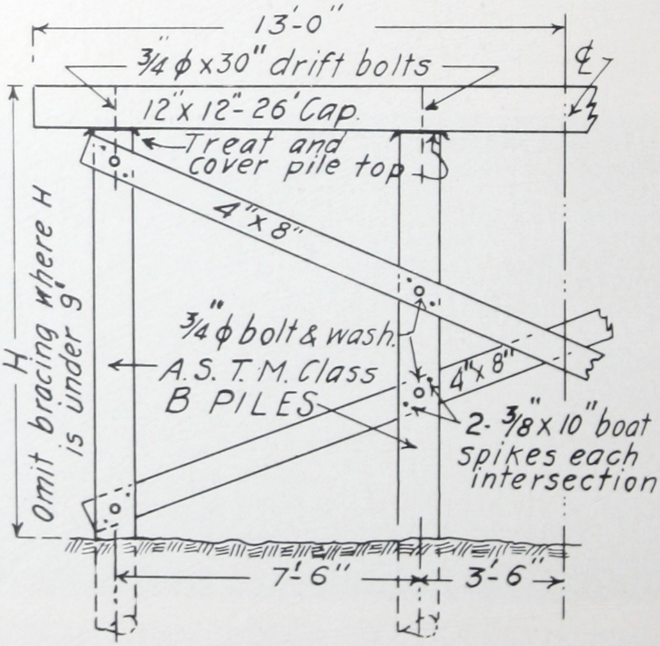
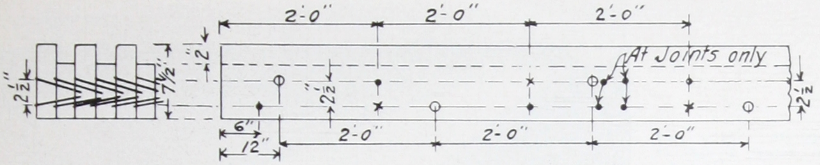


Fig. 7(a).—Typical Pile Bent



Note!
x denotes nails in first row
o " " " second "
• " " " third "

Note!
Set nail heads so plank fit tight

Fig. 7(b).—Nailing Diagram for Laminated Timber Base

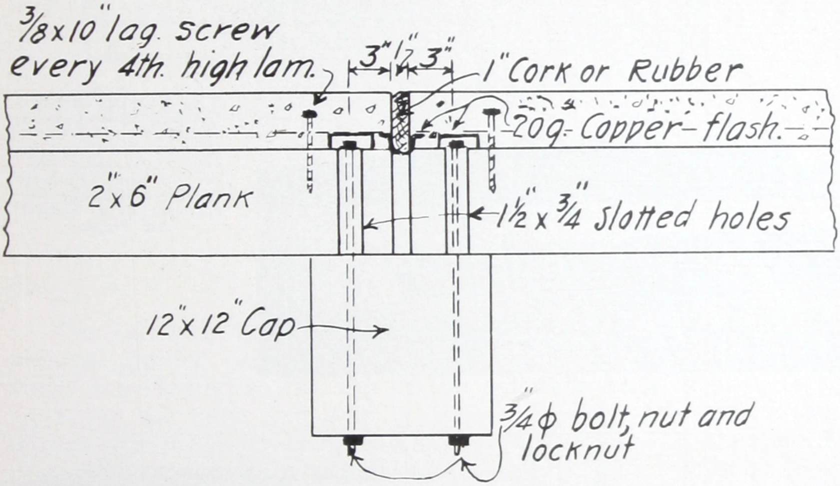
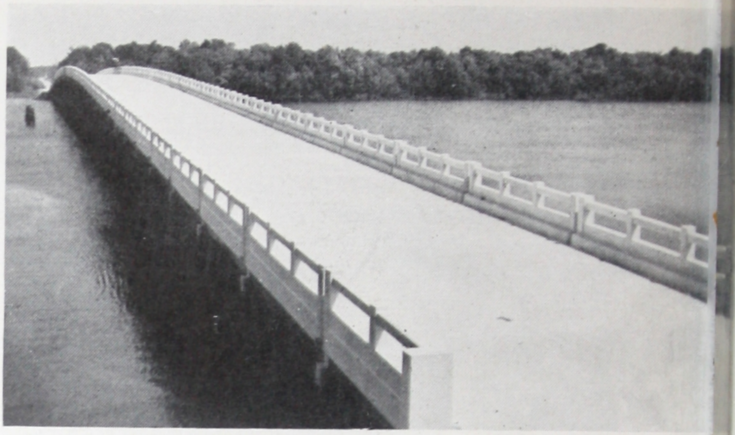
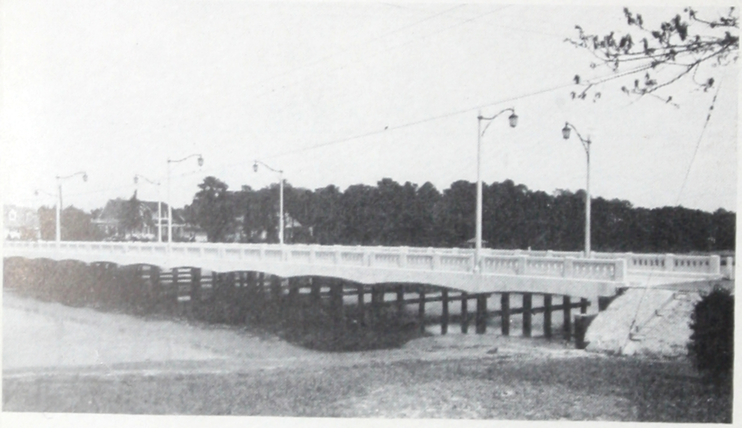


Fig. 7(c).—Detail of Expansion Joint

which would be required in longer structures. Expansion joints are generally omitted in decks of structures less than 160 ft. in length. For longer decks expansion joints should be placed at convenient bents so that the distance between them does not exceed 160 ft. or, at the most, 200 ft.

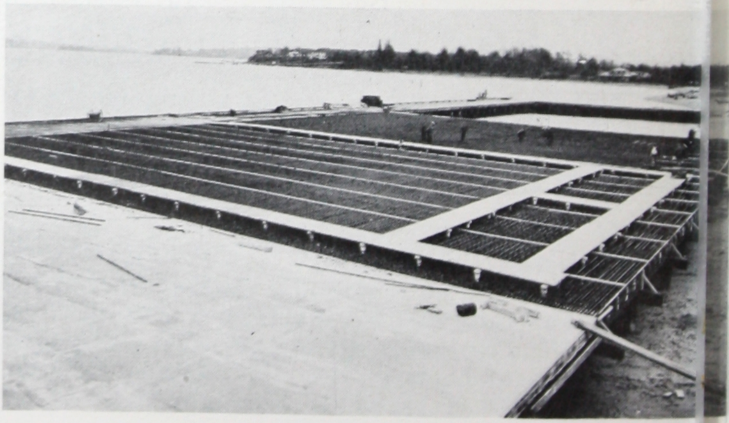
Composite Deck on 104th Street Bridge at Jacksonville, Florida. Necessary Clearance over Navigable Channel Is Obtained by a Vertical Curve. Structure Is Located on a Cut-Off Route for Heavy Traffic Between Jacksonville and Tampa





The 260-Ft. Bridge Crossing Silver Lake at Rehoboth, Delaware, Consists of a Composite Deck on Creosoted Timber Pile Bents. Built by the State Highway Department as a Federal Aid Project

Composite Deck for Royal Canadian Air Force Designed to Serve Heaviest Type Equipment. Beyond the Finished Section May Be Noted Reinforcing Bars in Place and Runways for Depositing Concrete on Timber Sub-Base



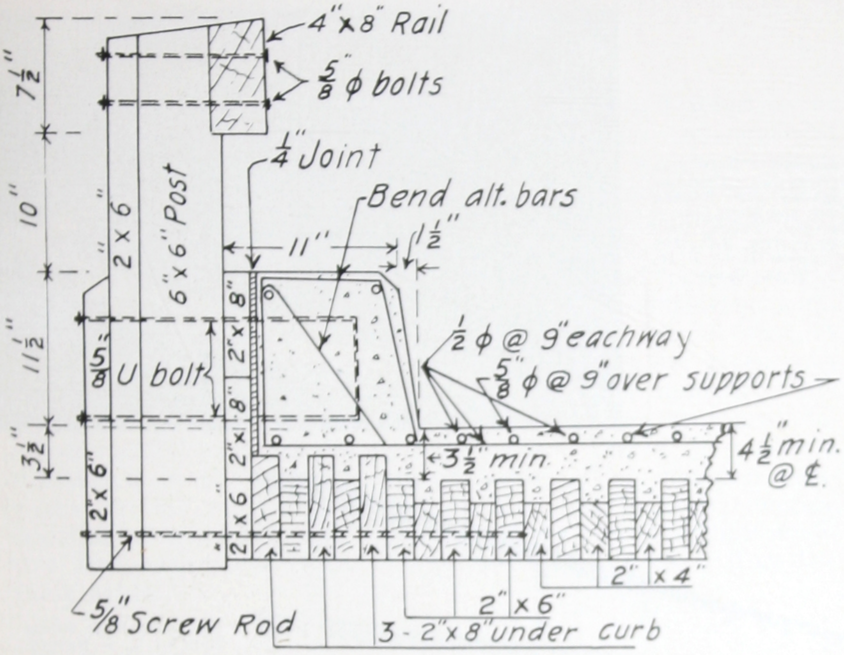


Fig. 8.—Suggested Design of Composite Deck with Timber Rail

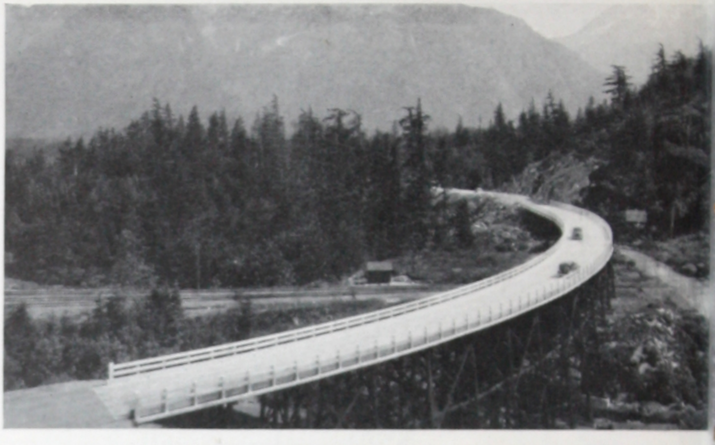
Rail

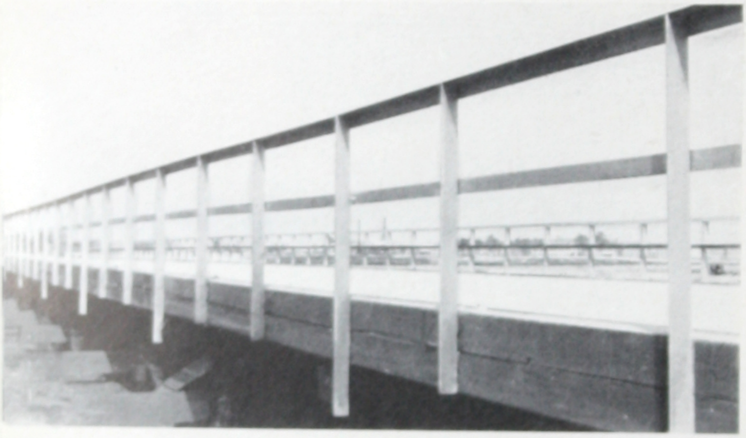
The rail may be of any type desired. An effective and economical timber rail is shown in Fig. 8. The outside timber strips are carried to the top of the concrete curb to provide a form for the curb and side of the deck slab. For either the timber rail or the concrete rail shown in Fig. 2(a), posts should be placed at the bents and at each one-third panel point except in the case of spans 16 ft. or less, where one intermediate post is sufficient. Double posts are used at bents where expansion joints occur.

Drainage

Provisions for deck drainage are similar to those in common use for concrete decks. Galvanized metal pipe may be carried through the deck or curb at the curb line, or openings may be left in the curb at suitable intervals to provide escape for water accumulating on the roadway or walks.

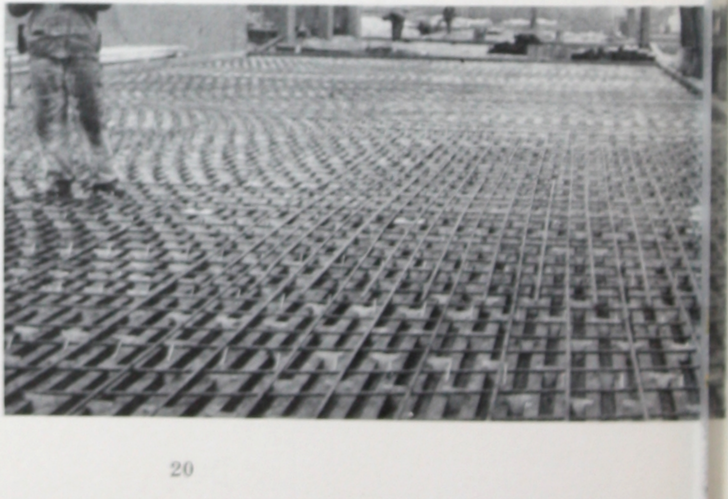
Composite Deck on Bridge on Canadian Highway over Johnson Creek and Main Line of Canadian Pacific Railway at Haig, B.C. The Alignment is on a 14-Degree Curve





Composite Deck Bridge Built by U. S. Navy at Air Base, Norfolk, Virginia. The Superstructure of This 286-Ft. Bridge Was Completed and the Bridge Opened to Traffic in 13 Days

U. S. Coast Guard Wharf on Long Island, New York. Uplift Spikes in High Laminations Inclined Toward near Support Reinforce Shear Connection



APPENDIX A

Tables I and II* and Fig. 9 permit the rapid selection of sections adequate for span lengths and loads usually encountered in practice. Fig. 9 shows sections, properties of which are given in Table II. Table I gives live load bending moments for H-15 and H-20 highway loadings on a 1-ft. width of slab for spans of 16 to 26 ft., also dead load moments induced by the weight of the deck itself. Dead load moments are computed for the weight of deck that is likely to be used, and may be considered sufficiently accurate for design purposes. In the table the percentages of live and dead load moments required in design are given with and without impact. Table II gives the resisting moment of the various composite sections commonly used and the structural elements needed to check the timber stresses. Use of the tables is illustrated in the problem stated below. The midspan composite section may be selected on the basis of the concrete resisting moment given in Table II, and the corresponding negative composite section over the support then checked from the same table.

DESIGN PROBLEM

To illustrate the use of the tables, select the span layout and design the deck for the following highway bridge:

Roadway width between curbs—24 ft. Crown not less than 1 in.

Loading—H-20 of the A.A.S.H.O.—a 20-ton truck with 0.4 load on each rear wheel.

Two end spans at 18 ft. from back face of abutment cap to center line of first pier (17 ft. 6 in. center to center of bents).

Three intermediate spans at 20 ft. center to center of pier caps.

Total length of bridge 96 ft. back to back of abutment caps.

Selection of Composite Section

The section at midspan and support must be adequate to resist, respectively, 70 per cent and 50 per cent of the simple beam live and dead load moments. Since the section is selected

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*Table II computed for stress in steel of 18,000 lbs. per square inch and in concrete of 800 lbs. If higher concrete stresses are desired, other structural elements in the table may be used, and resisting moment for midspan composite section computed for any desired concrete stress. Properties of composite support sections computed for reinforcement shown in Fig. 9 and must be recomputed for other areas of steel over the support.

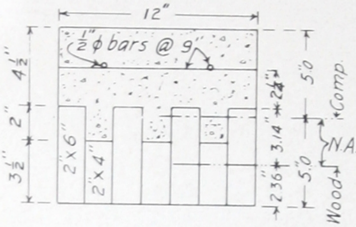
Table I.—Bending Moments for Design of Composite Slabs

Item	Span Length											
	16 Feet		18 Feet		20 Feet		22 Feet		24 Feet		26 Feet	
	Loading		Loading		Loading		Loading		Loading		Loading	
	H-15	H-20	H-15	H-20	H-15	H-20	H-15	H-20	H-15	H-20	H-15	H-20
Live load per foot width:												
Concentration per foot width—Lbs.	2,400	3,200	2,400	3,200	2,400	3,200	2,400	3,200	2,400	3,200	2,400	3,200
Simple span moment—In. lbs.	115,200	153,600	129,600	172,800	144,000	192,000	158,400	211,200	172,800	230,400	187,200	249,600
Per cent midspan moment—In. lbs.												
85 per cent	97,920	130,560	110,160	146,880	122,400	163,200	134,640	179,520	146,880	195,840	159,120	212,160
70 "	80,640	107,520	90,720	120,960	100,800	134,400	110,880	147,840	120,960	161,280	131,040	174,720
50 "	57,600	76,800	64,800	86,400	72,000	96,000	79,200	105,600	86,400	115,200	93,600	124,800
40 "	46,080	61,440	51,840	69,120	57,600	76,800	63,360	84,480	69,120	92,160	74,880	99,840
Dead load:												
Per linear foot—per foot width—Lbs.	85	90	90	95	100	100	100	100	110	110	113	113
Simple span moment—In. lbs.	32,640	34,560	43,740	46,170	60,000	60,000	72,600	72,600	95,040	95,040	114,580	114,580
50 per cent dead load moment—In. lbs.	16,320	17,280	21,870	23,085	30,000	30,000	36,300	36,300	47,520	47,520	57,290	57,290
Live load moment with 30 per cent impact:												
Per cent midspan moment—In. lbs.												
100 per cent	149,760	199,680	168,480	224,640	187,200	249,600	205,920	274,560	224,640	299,520	243,360	324,480
85 "	127,300	169,730	143,200	190,944	159,120	212,160	175,032	232,376	190,944	254,592	206,856	275,808
70 "	104,832	139,776	117,936	157,248	131,040	174,720	144,144	192,192	157,248	209,664	170,352	227,136
50 "	74,880	99,840	84,240	112,320	93,600	124,800	102,960	137,280	112,320	149,760	121,680	162,240
40 "	59,900	79,870	67,390	89,860	74,880	99,840	82,370	109,820	89,860	119,810	97,340	129,790

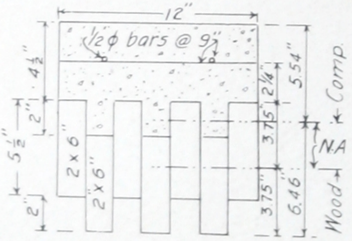
Table II.—Properties of Sections Shown in Fig. 9

Section	Moment Inertia I	Resisting Moment		Distance to Extreme Fibre y		
		Concrete	Steel	Wood	Concrete	Steel
Midspan Section—Composite						
1	1,000	160,000	....	5.00	5.00	....
2	1,397	202,000	....	6.46	5.54	....
3	1,397	202,000	....	6.46	5.54	....
4	1,728	230,400	....	6.00	6.00	....
5	2,541	299,000	....	7.70	6.80	....
Support Section—Composite						
1 (a)	349	....	83,750	3.75	....	4.00
(b)	455	....	126,500	4.30	....	3.45
2 (a)	508	....	104,500	5.09	....	4.66
(b)	654	....	153,100	5.65	....	4.10
3 (a)	508	....	104,500	5.09	....	4.66
(b)	654	....	153,100	5.65	....	4.10
4 (a)	626	....	116,000	4.57	....	5.18
(b)	809	....	168,000	5.13	....	4.62
5 (a)	887	....	141,900	6.00	....	6.00
(b)	1,436	....	254,100	6.58	....	5.42
Midspan Section—Wood						
1	117	....	....	2.36	....	....
2	232	....	....	3.75	....	....
3	232	....	....	3.75	....	....
4	313	....	....	3.33	....	....
5	512	....	....	4.75	....	....
Support Section—Wood						
1	78	....	....	2.36	....	....
2	155	....	....	3.75	....	....
3	155	....	....	3.75	....	....
4	209	....	....	3.33	....	....
5	342	....	....	4.75	....	....

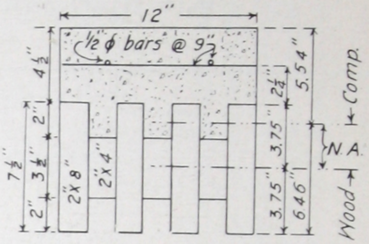
Fig. 9.—Composite Deck Sections, Properties of Which Are Shown in Table II



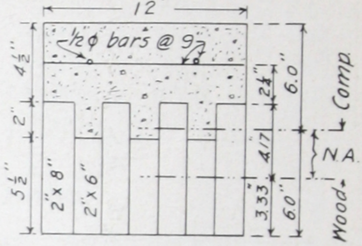
Section 1



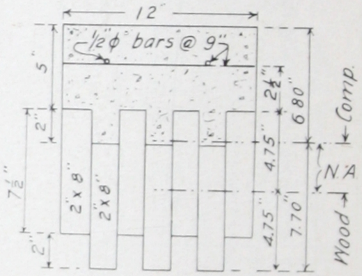
Section 2



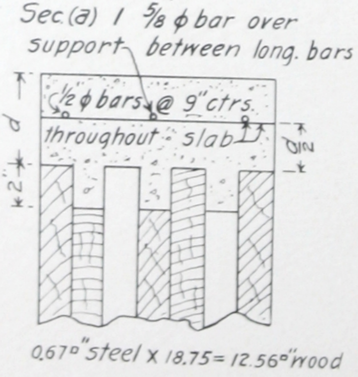
Section 3



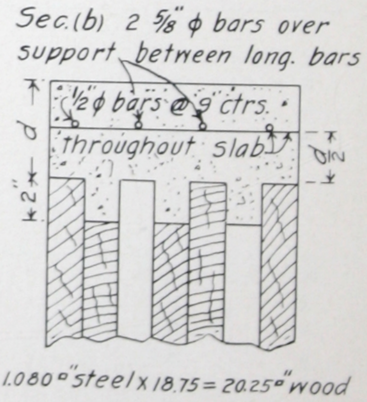
Section 4



Section 5


Sec.(a) 1 5/8" ϕ bar over support between long. bars
$\frac{1}{2}$ϕ bars @ 9" ctrs. throughout slab
d
2"
d/2
0.67□" steel × 18.75 = 12.56□" wood

Section (a)


Sec.(b) 2 5/8" ϕ bars over support between long. bars
$\frac{1}{2}$" ϕ bars @ 9" ctrs. throughout slab
d
2"
d/2
1.080□" steel × 18.75 = 20.25□" wood

Section (b)

on the basis of concrete and steel stresses, the moment values used must include 30 per cent impact. From Table I, for the H-20 loading and 20-ft. span, 70 per cent of the simple beam moment with 30 per cent impact is 174,720 in. lbs. Fifty per cent of the simple beam moment with 30 per cent impact is 124,800 in. lbs.

From Table II, section 4 has a resisting moment for the composite section at midspan of 230,400 in. lbs. and is, therefore, sufficient at this point. In the same table, under composite section at support, two sections—4(a) and 4(b)—are listed. These differ in the amount of tensile steel used over the support as shown in Fig. 9. Section 4(a), since it has a resisting moment of 116,000 lbs., is inadequate for the 124,800 in. lbs. bending moment developed at the support. Section 4(b), however, has a resisting moment of 168,000 in. lbs., which is ample.

It remains now to check the timber stresses. From Table I the following proportions of dead and live load moment are taken:

50 per cent of simple span dead load moment = 30,000 in. lbs.
70 per cent of simple span live load moment without impact* = 134,400 in. lbs.
50 per cent of simple span live load moment without impact = 96,000 in. lbs.

Stress Calculations.—From Table II the moments of inertia (I) for the wood sections midspan and support are 313 and 209, each with a lever arm of 3.33 in. Corresponding values for the composite sections are, respectively, 1728 and 809. The timber stresses are, therefore:

Midspan—dead load $= \dfrac{30,000 \times 3.33}{313}$ = 319 lbs. per square inch
Midspan—live load $= \dfrac{134,400 \times 6.00}{1728}$ = $\underline{466}$ lbs. per square inch
Total stress in timber f_w at midspan = 785 lbs. per square inch

At support—dead load $= \dfrac{30,000 \times 3.33}{209}$ = 477 lbs. per square inch
At support—live load $= \dfrac{96,000 \times 5.13}{809}$ = $\underline{609}$ lbs. per square inch
Total stress in timber f_w at support = 1086 lbs. per square inch

Spacing of Shear Developers

With a lateral distribution of 4 ft., one rear wheel of the H-20 loading imposes a load of $\dfrac{16,000}{4}$, or 4000 lbs. per foot width of slab. With this load at the critical position (three times depth of slab from support), the end reaction is 3400 lbs., which an impact allowance of 30 per cent increases to 4420 lbs. The net section at the support for a 1-ft. width of slab is 118 sq. in. The maximum horizontal shear at the neutral axis is $\frac{4420}{118} \times \frac{3}{2} = 56.2$ lbs. per square inch, and $144 \times 56.2 = 8093$ lbs. per square foot. This requires—through the region of maximum shear—$\frac{8093}{1750} = 4.62$ shear developers per square foot of contact area, or a spacing in each groove of 9.6 in. Spacing will, therefore, be taken as 9 in. through the area near the support and gradually increased toward the span center to a maximum of 16 in.

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*Working stresses for timber include an allowance for impact up to 100 per cent. Impact is, therefore, neglected in computing the live load stresses in the timber.

Timber Required

If the timber rail and concrete curb design shown in Fig. 8 are used, each curb with its outside facing strips has a total width of 12½ in. at the deck level. The total width of deck to provide a 24-ft. clear roadway width and two curbs is, therefore, 26 ft. 1 in., or 313 in., requiring 193 strips 1⅝ in. wide, or 97 strips 2 x 8 in., and 96 strips 2 x 6 in. S4S.

Each strip, of course, will extend the full length of the bridge, or 96 ft., and to obtain the most effective arrangement of splices, pieces in a series of three strips should conform to the following lengths, in feet, the rotation to be continued across the bridge:

18——20——20——20——18
12——20——20——20——24
24——20——20——20——12

APPENDIX B

SPECIFICATIONS

Deck Lumber

Manufacture.—Individual pieces must be surfaced to a uniform thickness, with no variation in excess of 1/16 in. permitted. They shall also be of uniform width within a tolerance of ⅛ in. Pieces shall be cut to the exact lengths specified, and the ends shall be square.

Treatment.—Lumber shall be treated with a minimum of 8 lbs. of Grade One creosote per cubic foot in accordance with the current specifications of the American Wood-Preservers' Association.

Placing.—Pieces shall be placed in the structure with due regard, first, to securing full and accurate bearing on the supports for each individual piece. They shall then be brought to position by spiking, so as to maintain as nearly as possible, and without undue strain, the uniform depth of groove shown on the plans. A template block may be used for the purpose. Variation in depth of groove exceeding ⅛ in. within 5 ft. of the supports shall not be permitted. An additional tolerance of ⅛ in. in depth of groove shall be permitted throughout the balance of the span. Filler blocks for the bearing of the elevated laminations on the supports, where required, shall be accurately placed and nailed only to the caps with two 30d nails, driven vertically.

Spiking of Laminations.—Gage lines for horizontal spiking shall be carefully observed. Spikes in the upper gage line should be inclined slightly downward, and those in the lower gage line inclined slightly upward to prevent undue approach to the edges of the pieces. No protruding heads of spikes shall occur, but all shall be flush and well set.

Shear Developers

Manufacture.—Shear developers shall be manufactured to the exact dimensions shown on the plans, and of the material indicated. They shall be stamped out so as to avoid any rough and uneven edges.

Placing.—No slots shall be cut or shear developers placed until the deck timbers are all in place and completely spiked together. All slots for shear developers shall be cut by means of a tool approved by the engineer. In general, the tool shall consist of a steel or forged body in which a chisel blade is housed, with a suitable vertical member, preferably an integral part of same, to receive the blow of a minimum 8-lb. sledge or air hammer. The tool shall be so designed as to permit withdrawal of the chisel without splitting or other injury to the timber.

The chisel blade shall be of the best grade of heat treated tool steel properly tempered to withstand driving under the blow of the sledge. In general, it should be of material similar to that in the highest grade circular saws. It shall be the exact size, in dimension and thickness, of the shear developer, except that suitable provision for its attachment to the tool should be made. The blade shall be so placed in the housing that the slot can be cut to the full depth required for placing the shear developers.

The blade shall have cutting edges sharpened to a uniform angle on both sides, and care shall be taken to maintain constantly a keen, sharp cutting edge. For this purpose the contractor should have available at all times extra blades, well sharpened, for replacing dull blades. Obviously, the tool should be so designed as to facilitate prompt changing of blades when or if necessary. After the slot has been cut, the shear developer shall be set in place and driven home with a sledge weighing not less than 2 lbs., care being taken that it enters true and square, is thoroughly secure, and occupies the position shown on the plans.

Shear developers shall be accurately placed, as shown in the spacing diagram on the plans. However, where knots or other defects occur at the indicated location of a shear developer, its position may be modified slightly to avoid such defect.

Uplift Spikes

After the shear developers are in place, uplift spikes shall be driven in the high laminations at intervals of 2 ft., or as shown on the plans. They should penetrate the wood at least 3 in. and their heads should project above the high laminations so as to be well embedded in the concrete mat when poured. Spikes shall be inclined upwards about 30° from the vertical toward the nearer support. Alternate rows should be staggered and spacing should be slightly varied so that spikes fall between the shear developers.

NOTE.—The American Wood-Preservers' Association is the owner of patent No. 2,022,693, issued December 3, 1935, to James F. Seiler, entitled "Composite Wood and Concrete Construction." The policy of the Association is to make this construction available to the public without undue restrictions. Upon application, therefore, the Association will grant licenses, without charge, to those desiring to erect structures designed in accordance with the principles outlined in this bulletin, and employing timber treated in conformity with the standards of the Association.